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With the amplitudes shown for the square and pulse waves, the period of the waveforms is given by

$$T = 2 \times RC \times V_{pk} \left(\frac{1 + \tau}{\tau} \right)$$

where:

$$\tau = \frac{10\ V_{pk}}{R_1 + 12.2}$$

The duty cycle of the pulse train at point C may be expressed as

$$\text{duty cycle (\%)} = \frac{100}{1 + \tau}\ (\%)$$

The table shows a possible range of resistances for R_1, with the corresponding values of τ and the duty cycle of the pulse train. Resistor R_1 also limits the output current of op amp A_3. If the amplitudes of the square and pulse waves are different from those indicated here, the circuit equations must be modified.

To calculate the circuit parameters, first choose resistor R_1 to obtain the duty cycle desired. Next, fix either R or C (preferably the latter), and calculate the other parameters to obtain the desired frequency. The resistor values should be large enough to avoid loading the dividers, but not so high that bias current causes excessive offset.

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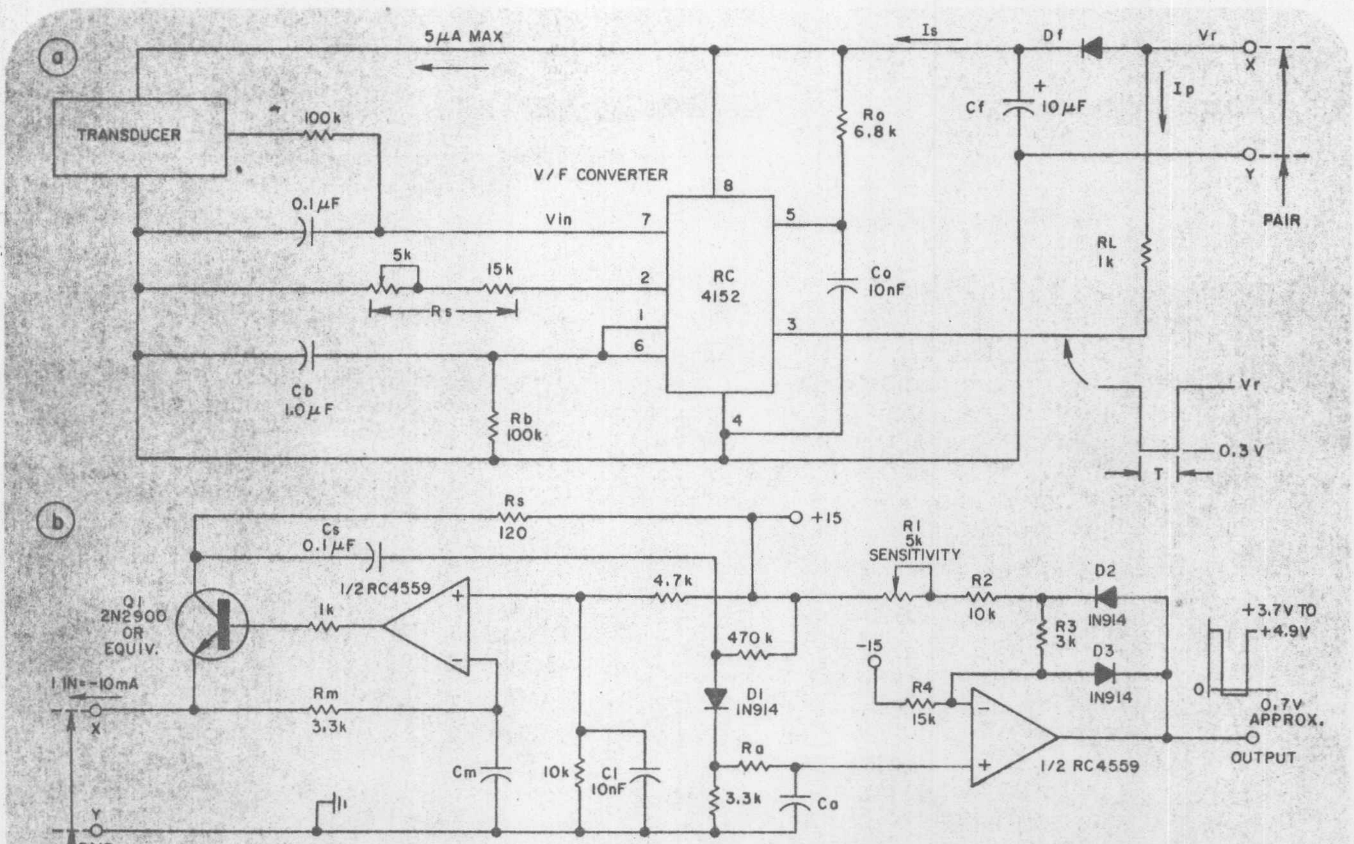
Transducer interface sends data over the pair that carries power to it

Just one twisted pair brings data from and carries power to the remote transducer interface in a low-cost data link that works over distances as great as 1000 ft. With power supplied from the receiving end, the transmitter needs neither batteries nor an expensive isolated power supply.

For the interface between the transducer and the twisted-pair transmission line, the transmitter uses a low-cost IC voltage-to-frequency (v/f) converter. The converter generates a train of current pulses with a frequency proportional to the transducer's output voltage; accuracy is 1% or better.



One pair of wires carries data from and power to the transmitter (A), which contains a voltage-to-frequency converter. Current pulses from this converter travel down the line to the receiver (B), which converts them to TTL levels. Transistor Q_1 provides low-impedance power to the transmitter, while passing current pulses from the transmitter to R_s, which converts them into voltage pulses.

In the receiver, these pulses are converted to TTL levels for subsequent processing. In addition to converting levels, the receiver sends constant-voltage power to the transmitter from a low-impedance stabilizer. Low output impedance ensures high common-mode rejection and excellent noise immunity.

With the circuit values shown in the figure, the transmitter (A) has an output frequency range of 0 to 10 kHz. Other ranges require changing current-setting resistor R_s and timing resistor R_b, as well as capacitors C_o, C_b and C_s (see table). Adding an input op amp improves the transmitter's accuracy to 0.05%.

In the transmitter, diode D_f isolates the transducer and converter from effects of the output current pulses. During each pulse, this diode blocks, and capacitor C_f supplies power to the local circuits.

The receiver (B) has two sections, one serving as a stabilizer that also converts the returning current pulses to a voltage, and one serving as a gain stage and level setter. The stabilizer uses the +15-V supply for its reference, so its stability depends on that of the supply.

Power to the transmitter comes from transistor Q_1, an emitter-follower current booster in the stabilizer. Resistor R_s is a collector load, which converts the current pulses from the transmitter into voltage pulses. Transistor Q_1 operates simultaneously as an emitter follower, to provide a stable voltage, and as a common-base amplifier for the incoming current pulses.

The remaining circuitry clips and amplifies the pulses from R_s to convert them to TTL levels having a rise time of about 2.5 μs. The RC4559 is used for its relatively fast response. Diode D_1 clips negative excursions to ensure that the output op amp does not generate large negative outputs. The output is set to TTL levels by the feedback network made up of diodes D_2 and D_3 and the resistor string, R_1 through R_4.

The op amp's output, which has a fanout of about 15, has a HIGH output level that varies with the pulse repetition rate. The lowest value (+3.7 V) of this level corresponds to a rate of 100 kHz and a width of 5 μs.

The transmitter, or source impedance, and the receiver, or load impedance, need not match the cable impedance. The receiver looks like a short to the transmission line, so a transmitted pulse is inverted when it is reflected. Diode D_f at the transmitter absorbs the positive reflection to prevent any further reflection back to the receiver.

Operating range	C_o	C_b	C_s
0 to 1 kHz	0.1 μF	10 μF	1 μF
0 to 10 kHz	10 nF	1 μF	0.1 μF
0 to 100 kHz	1 nF	0.1 μF	10 nF

The transmitter's output pulse width is approximately 1.1 (R_oC_o), which is 75 μs for the values shown. The scale factor is

$$\frac{F_o}{V_{in}} = \frac{R_s}{T\, R_b\, V_{ref}}$$

where F_o is the output frequency and V_{ref} is 2.25 V. The output current pulse is

$$I_p = \frac{V_r - 0.3}{R_L + 2\, R_t}$$

where R_t is the resistance of one conductor of the twisted pair, calculated from its resistance per foot.

Noise filtering in the receiver can be tailored to cope with electromagnetic interference from such sources as motors and power lines, without degrading performance. Capacitor C_m controls the response time of the regulator, and the R_aC_a network forms a low-pass filter for the output stage.

For a 75-μs pulse width, typical values are 5 nF for C_m, 1 nF for C_a, and 1 kΩ for R_a. In terms of the transmitter's timing components,

$$R_aC_a \approx \frac{R_oC_o}{20} \quad \text{and} \quad C_m \approx \frac{R_oC_o}{4R_m}.$$

Finally, the sensitivity control should be adjusted for proper output levels and minimum pulse jitter.

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CIRCLE NO. 313

IFD Winner for February 1, 1979

Bob Ferguson, Systems Engineer, Computer/Federal Systems Engineering, Motorola Semiconductor, M/S Z315, 5005 E. McDowell Rd., Phoenix, AZ 85008. His idea "Simple Protective Circuit Ensures Proper Power Sequence to MOS RAMs" has been voted the most valuable of Issue Award.

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